Latest Developments for Pipeline Girth Welds using 3D Imaging Techniques

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Content of presentation

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• What do we expect from imaging methodology?
• Principles of ultrasonic imaging
• IWEX imaging for Pipeline Girth Welds inspection
• DNV-GL qualification activities & results
• Operational benefits
• Current system status for Carbon Steel & CRA inspection
• Questions
Standard A(UT) Data displays

• A-scan (time/distance – amplitude)
• B-scan (color coded A-scan, or grey scale i.e. ToFD)
• Strip charts (amplitude, transit distance, mapping)
• S-scan (Sectorial scans, fixed transition point, variable angle)
• Linear scan (variable transition point, fixed angle)
What are we expecting from new methodology?

- Inspection result presentation must be generated to present the defects in its true orientation, position and size
- Straight forward result display (no strip charts) and less subjective interpretation of operators
- Detection ability independent on defect shape and orientation
- 3D image of weld geometry and welding imperfections in a single presentation
Imaging technologies in other fields

In other industry fields the imaging technique is already in use;

• Medical field
• Seismic field

The objective of imaging technique is to:

• Illustrate shapes and features in its true context
• Straightforward and unambiguous result display
Seismic imaging, and potential for AUT

• An ignition source is required and an array of recording sensors to measure wave fields

• Based on measurement and data processing concepts applied in *Seismic exploration*

• Algorithm processes the information into *2D and 3D images*

• *New AUT methodology is based upon same principles*
IWEX Ultrasonic imaging

• The FMC data forms an acoustic ‘fingerprint’

• Per scan increment resolution (circumferential direction), all combinations of Source – Receiver elements are executed, recording all acoustic wave forms

• Scanning process starts with first Tx element (T(1)), all other receivers are in the DATA receiving mode, until the last element (T(64)) within the array.

• Standard AUT PA system hardware is used with standard PA probes having each 64 elements

• IWEX uses 2x64= 128 elements

• The data set obtained is called **Full Matrix Capture (FMC)**
Principles of Ultrasonic (IWEX) imaging

- Imaging area consist out of pixels
- Back propagate wave field to each pixel: Inverse Wave field EXtrapolation
- The value of the pixel is the amplitude from the back propagated wave field

Received A-scans per element

Element #

\( t \)

\( x \)
Principles of Ultrasonic (IWEX) imaging

This value is referred to as **image amplitude**

Summation of all contributions and assign the amplitude at t=0 to the pixel location

Time shifting $\rightarrow$ back propagation $\rightarrow$ Inverse Wavefield Extrapolation
Principles of Ultrasonic (IWEX) imaging

• The image amplitude is calculated for each pixel in the image area, per pixel location the process is similar to a focused beam.

• From the different IWEX inspection modes, the highest amplitude is presented in the image, other modes can be separately displayed as well.

• Different color pallets can be used.

• Random noise is cancelled out by the summation of process.

![Image of color palate from 0 to 400 units (%)]
The Applus RTD IWEX™ automated ultrasonic testing procedures have been subjected to qualification trials.

IWEX is an ultrasonic **imaging technique**, which is presently a non-conventional ultrasonic technique for the pipeline girth weld inspection application.

The qualification work has been done under agreement between Applus RTD and DNV GL AS, and follows the requirements of:

- DNV-OS-F101:2013; RP-F118:2010

Qualification included:

- Weld Configurations: J3, J4, J6, J8, V15, V20, V25, V30
- Wall thickness range: 21 – 41mm
Porosity M093

- Weld 24” x 21.3mm J8 Bevel Carbon Steel
- IWEX presentation of Porosity
- Weld no. 4 Position 1743
Planner M082

- Weld 24” x 21.3mm J8 Bevel Carbon Steel
- IWEX presentation Planner defects
- Weld no. 4 Position 287
- Ligament between defect and ID surface can be easily identified and measured
Stacked Defect M099

- Weld 24” x 21.3mm V15 Bevel Carbon Steel
- IWEX presentation Stacked defects
- Weld no. 5 Position 596
- Stacked defect discrimination (combination of LOIF & LOF)
Ligament M003

- Weld 24” x 41.4mm J3 Bevel Carbon Steel
- IWEX presentation Planner defects
- Weld no. 9 Position 359
- Ligament between defect and ID surface can be identified and measured
The general POD curve is regarded valid for all zones and areas (root, buried and cap) of the weld, all types of imperfections except Cu inclusions and all lengths of imperfections to be 0.66mm (90/95% C).

The detection limit is observed to be for single pores with diameters below 1.0 mm. It should be noted that planar indications with some length, measured down to 10 mm are consistently reported with documented vertical imperfection heights below 0.5 mm.
The general height sizing accuracy (the 95% limit against under-sizing) is estimated at -0.77 mm under sizing.

The mean height sizing error is found at 0.17 mm, with a standard deviation of 0.57 mm. In general, the depth position accuracy of the IWEX is considered as accurate, in particular when well resolvable responses are observed with the cross modes.
IWEX used on CRA material

- Shear waves are known to have a limited performance (SNR) due to grain structure
- Grain structure may affect the focusing performance, as beam path are slightly different then calculated
- The back wall may not be a ‘perfect’ mirror due to the clad layer
- Additional IWEX modes can be used and an optimized wedge design is used to accommodate compression and shear wave modes
- Same PA system hardware is used for CRA inspection as for standard Carbon Steel
Side drilled holes

- 1.5 mm side drilled holes are clearly imaged in the weld volume and in the hot pass area.

IWEX direct long mode

Side drilled holes in the hot pass area
Flat bottom holes

- 3 mm flat bottom hole following the weld bevel
- Upper and lower tip diffraction are imaged
- Better signal to noise ratio
IWEX CRA test weld

IWEX direct shear modes

IWEX tandem shear modes
IWEX CRA test weld

Left probe, direct path through weld
Operational Benefits of IWEX imaging

- Inspection set-up is independent from weld bevel configuration design, this will result in lesser calibration blocks.
- Inspection set-up is tolerant for probe positioning and don’t require scribe lines to line-up the guiding band.
- Accurate measurement of defect ligament enabling the use of interaction cases as outlined in e.g. API 1104 A6 and BS7910.
- Sizing of imperfections does not depend on a calibration reflector, this is valid for height, length and depth.
- The IWEX imaging methodology results in more accurate sizing and positioning of flaws.
- Inspection concept for inspection of coarse grained welds (CRA, LNG) is feasible.
Questions?

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